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CANADIAN PATENT

LINER EXPANDER

Joe C. Stall, Tulsa, Oklahoma, U.S.A.

Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

APPLICATION No. 897, 460

FILED PRIORITY DATE

No. OF CLAIMS

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38s, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 45, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

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The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such 10 as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft 13.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein $P_{\mathbf{c}}$ is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

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approximately one inch, at which the longitudinal deflection was approximately:
0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

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- 1. A device for expanding a metallic liner inside a conduit which device comprises a shaft element, an expanding die member attached to said shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against said liner by a substantially constant force.
 - 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said cone member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
 2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a

 sleeve-like element connected to said movable bearing plate member and

 slidably positioned on said shaft and a member connected to said shaft to

 limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.
- 1 7. A device for installing an expanded metallic liner in a conduit 2 which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed 3 circumferentially around the outside of said shaft and being pivotable out-5 wardly therefrom to contact the liner; a conical expanding member slidably 6 positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each 7 8 having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, 9 each slidably positioned on said shaft and contacting opposite ends of said 10 11 columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a 12 differential screw element connecting said shoulder and said shaft to apply 13 14 a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the 15 16 axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members . 17 18 outwardly with a substantially constant force.

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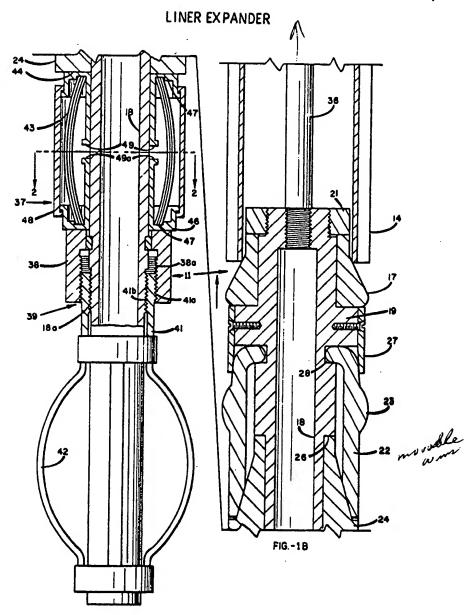
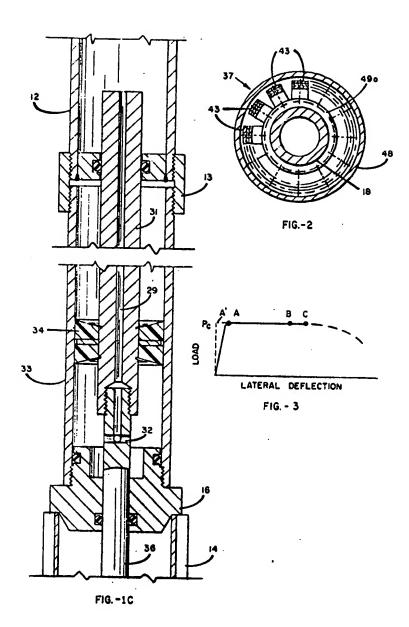


FIG. - 1A



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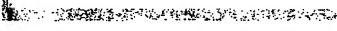
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I. A device for expending a metallic line; insules a conduct which device comprises a shift alment, an expending the number obtained to said that closure, said the member comprising a movelle liner-forming member positioned on said shaft and being carially movelle in respect thorsel to contact said liner, as expender member alidably positioned on said shaft between said shaft and said shaft the member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft to contact said sequence system and to maintain said expenser member against the contact said suppose and to maintain said expenser member against said liner-forming member, sharely said liner-forming member, sharely said liner-forming member is urged against said lider by a substitutially constant freque.

2. In a device for installing an extended metallic liner in a conduct wherein an expanding size is noved through a liner portional in sale statistics to exploit suid liners a cylindrical staff almost, so expanding size another attached to enid shaft, said size senter comprising a plurality of arm members disposed around said shaft and being pivotable untarrity therefrom to statistic liner, a cone number alicially positioned on said shaft between said shaft and said ans members to very said arm members calcately from said shaft, and a constant force spring number positioned on said staff to contest said once number and a suid staff to contest said once number and to maintain said once number in contact with said arm members, whereby said arm bootness are argued outwardly by a substantially constant force.

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- . A. The device of Claim 3 wherein ends compression grows comprises a differential surver consecuting make apring number and said shaft.
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- 6. The device of their 3 whereis said columns have a machingular gross-section, the width being greater than the Mickesow, and bening the sider flow means to the dissector of male shaft.
- 7. A geries for installing on expended ustallis listy in a comisti which comprises a syliminated, shaft classical on expending dis senter mounted on mid shall, said the number comprising a planshity of use senters disposed eforestially around the outside of said sheft and being pivotable setearly therefrom to contact the liner; a scalest expending maker slidely postitioned on smill short between said shaft and mild are employed to supp said are masters outsandly from suid shaft) a plurality of slander columns, each basing a long reutangular opposatestion and disposed eireasperentially about suid thait; an upper bearing plate member and a lower tearing plate misher; each slightly positioned on said shaft and conducting opposite order of said columns limiting also we attached to each of sold bearing plate numbers and although positioned as said staft; a shoulder maker on said shaft; a differential score elevent connecting will shoulder and said should to apply stiling look to mid columns; said thousan being consequable with the we memorial to entil lower bearing plate mester, wherety the axial travel of said bearing plate members is limited; said column numbers breassithing their buckling lood to said arm numbers to urgs said arm speak cutsurely with a substantially constant force.

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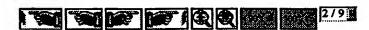
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Figure 14, 15 and 16, taken together, convicture a partial retional view of a preferred embodiment of a liner expending tool according to the present investion; and

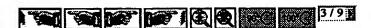




Tigure 2 to a sectional view of the apparatus of Figure 14 taken at

Figure 5 is a typical plot of applied lock versus Deflection for the constant force spring device of the Lavesticn.

Referring to the drawings, Figure 1A is the bottom portion of a liner expending took for one in installing a modulike liner in a well, while Pigure 19 illustrates the middle section of such a tool and Pigure 20 represeats the upper section of the tool. The expending took il is ableabed to ctassers well taking 18 by ampling 15 out, applically, may be lowered from the surface through a well easing (not shown) to a point in the cowing at which it is sesired to invisit a metallic liner. Before inserting the test into the well, as alongsted vertically corrupted liner in fabricated from alle stead, or suitable mileable material, is placed on the tool. The corrugated liner is occured in position by esentant at its upper end with a cylindrical shoulder marker 16 and, at the lower and by contact with a first-stage espanding dis 17 in the form of a trumested circular core which serves as a firstsaling die in the spream hereinefter described. The expanding die is fixedly shianhed to a centrally lossted, elongated mylindrical bollow shaft ld which forms a portion of the body of the tool. As shows, the expending size 17 20 is held in place between a lower shoulder 19 and coller 21 threaded outo the short. . A plurality of moveble arms 29, preferably provided with outsardly salarged portions 25 sear the top, are disposed in the form of a sylinder of that's 18. The enlarged purbloss of the some 23 upon being moved outvertly equiest the liner to perform the final step of expending the sorregisted. liner into a entertantially sylictrical shape. The are members II are pivotally of to the shelt so as to be movehle outsurally from the shelt by a tapered expending number 26 although positioned on the sheft to serve on a second-stage expender. The series of the masket 2h, as shown, mover specially along the shart to angage with the arms and more than outvertly. Advantageously, the form setting sentions, typically cotegonal is shape. The expension of the arm ers is controlled by the position of the member 20 which moves squardly



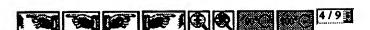
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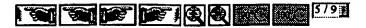
The expending tonl, comprising the first-stage die and the secondstage die is drawn through the liner to expend to the place in the casing. The first-stage die prevides a gross differention of the liner so that it is expended outwardly against the wall of the sening. The second-stage die them passes through the liner and performs the final expension to excel the liner surface of the liner and to provide more even contact between the liner and the wall of the casing and effect a finid-light seal-

In operation, the liner setting tool is assembled at the surface, so described shore, and a glass cloth saturated with a rectaous natural may be med the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such on odl, is then people under pressure down the well tubing and flows through the rescountary 29 provided is golished rot 51, through parts 52 and into exitader 35 commetted to the upper soll of the shoulder 16. Upon the application of finish processes to the cylinder, the pieton 34 seconds to polished roi 31 nowe upwertly in spinner 33. As shown, rot 36 commonts polished rot 31 and shaft 15 spon skich is nomical the first-stage expending size 17. Then the piston % to meetally through the sylindar 33 the expending die 17 and the secondstage die 22 ure draws upwurdly into the corrupted lists it and "iron out" the correspisors in the limer, so that the expected liner may contect the inside well of the casing in which it is being installed. Positioned on the shaft below the expending menter in is a communitary tures spring menter 37 which is employed to true the experding number equinst the explaining error 22 with a substantially sometant force. The force exerted against the are sembles being emetentially extetant, the force transmitted through the are members to the 30 lisey and to the during will be substantially constant on that either skidling of the tool in the casing or repture of the casing is precluded. Or course, the three provided by the spring maker is preselected so that the frictional



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forces between the tool and the liner and the presence emerted designs the oneing are maintained at presentanticed safe levels. The constant force spring
number ensures that the coverant pressure between the liner forming portion 25
of the corn 22 is great except to previde the Soriced deformation of the coning. while resounting demons to the ensing or to the tool.

The speakest force upring eacher 77 is alignly momes on the shaft is end half between the expending alongst 26 and a sylindrical lower choolder sender 36 forming a portion of a differential screw classest 39 which beausests the looking on syring number 37 to shaft masker 18. The differential curve alongst complete shaft masker 18 on the outside of which are set sets threads like, the lower number 18 provided with founds through 55s and thinks number \$1 provided with threads on the shaft out the shoulder. The two cets of threads are source, such as square, modified square, or home threads, to withtened very high loads and differ in pitch so that moulder 35 is square specify on the shaft 18 when the shaft 18 revolved relative to thinks \$1. The shoulder 35 is secured to the shaft 18 to options \$5 so that it can alide longitudinally, but it is not free to rotate on the shaft. Finally attached to the lower sed of the thinks is a friction number, such as the infinite is a friction number, such as the infinite will of the another, such as the infinite squared to the shaft. Preferably, the direction of the shoulder masker threads 18s is the same as that of the should are slightly greater than these of threads 38s is the same as that of the shaft threads 18s, e.g. right-hand threads. She is the pitch, or load, or threads 18s is alightly greater than these of threads 38s, with the pitch, or load, or threads 18s is alightly greater than these of threads 38s, with the pitch, or load, or threads 18s is alightly greater than the of threads 37s to advance upward alightly and a compensation load is curred upwardly on apring alument 37 to come buchling. For example, one estimatory threads on a short approximately 1.7-inch outside dissector and five and threads incide dissector.



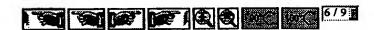


Denotes force spring e)meant 37 comprises eather 63, attentageously contricting of a pixelity of alongsted columns disputed around short 18. Oppor bearing plate samber 14 is in contact with the apper ends of the actions and is aliabily positioned on short 18 to tremost the force of the spring longitudinally against the bottom and of expender sensor 24. Insert bearing plate number 16 contacts the lower ands of the columns and is served against along the sanft by longitudinal movement of lower shoulder 50 on a result of revolving differential movement 39. Grooves 37 are provided in such or the bearing plates, to form as upper race and a lower race, into which the code of the columns are inserted. These grooves may be simped to contain with the shape of the column ands if decired. A cover 48 may be employed to amilian foreign matter from the spring mechanism and to protect

A means for limiting the deflaction of the columns to required. Although the column element functions in a bushed condition, application of specialize compressive lead thereto would sense total failure or repture of the solumns. Therefore, a pair of stops by each type are provided for this purpose. As shown, the stops are rigidly commerced to the bearing plates, and, in effect comprise upper and lower limiting starves positioned on the shaft to alide longitudinally thereon. The sude of the stops may some toward, or sway from, each other as the load on the spring number vertex. Lower places is prevented from moving dams by loader shoulder 56 acmeeted to the shaft 16. However, the specing between the sude is much as to limit the longitudinal travel of the bearing plate numbers as they more together to prevent permanent deformation of the column almosts 55. Writous alternative manus for preventing samage to the column almosts 55. Writous alternative manus for preventing samage to the column almosts by also be employed. For example, plas or rings accepted on this chaft may serve as stops, or the cover 48 provided of estimable consentions may be suplicied for this purpose to limit longitudinal and/or lateral aerlaction of columns.

The columns of the column element 45 may be arranged erosed the grant 16, which as shown here forces a portion of the body of the spring fartner, with make of the columns fitbad to the recen by. The soluble may be

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ritted closely together as shown, or say he spared around the race, with representers used between them to meintain the desired spacing. The runder of colleges employed will depend upon college characteristics and the emissis of construction. For example, the standarders reduced in the column may be varied withly, sed the column cole say to roted, flat, fixed or hinged. The preferred construction is a thin, element column with neuroscience, free to now within the races shaped to the convenient of the solumn cole. Materials which may be estimated to the surveiters of the solumn cole. Materials which may be estimated and activated for the column are continued and low alloy stocks, chronium and minimal-chronium statistics stocks, vertices exper how allows and other similar saterials providing activated establess stocks allows and other similar externals providing activated properties. Typically, the individual columns are or long represental properties. Typically, the individual columns are or long represented as that the wider lace of the universe is someth to the dimenter of the shart. Thus, with surfacient conspression leading, the columns backles, and hand about the acid having the loars secure of inertia, e.g., outwardly may from the shart 18.

For exemple, a group of columns 0.167-inch thick by 0.836-inch wife by 10.626-inchwe long, with the ande rounded, were februard from A.f.S.I him wheel, question and draws at 573°F. Buth column was found to require a critical suppression looking of 550 pounds in order to buckle the salumn. After buckling, the calumns were found to have a very filet spring characteristic, as shown in Figure 3, wherein Pa is the critical buckling look and point of represents the look and deflection at which the airces is the extress Tibers of the solumn exceed the yield point of the untertal. Theoretically, the chape of this spring characteristic curve is described by earts 04'ABO. Solutily, this curve is described by thill due to friction in the system. Potobe A and I represent typical working limits, which, of course, say he varied according to the application for which the spring is designed. For example, where a large number of floring cycles are not enticipated, a working stress just below the yield point may be used, while with a great number of florines, the working stress may be held to less than the enforces limit of the entertal of construction. In the above-namifound tests, the lateral disflection was limited to





approximately one inch, at which the longitudical defication was approximately 0.825 inches. From more defination to the account defication, the \$50-pound loading was found to be substantially constant.

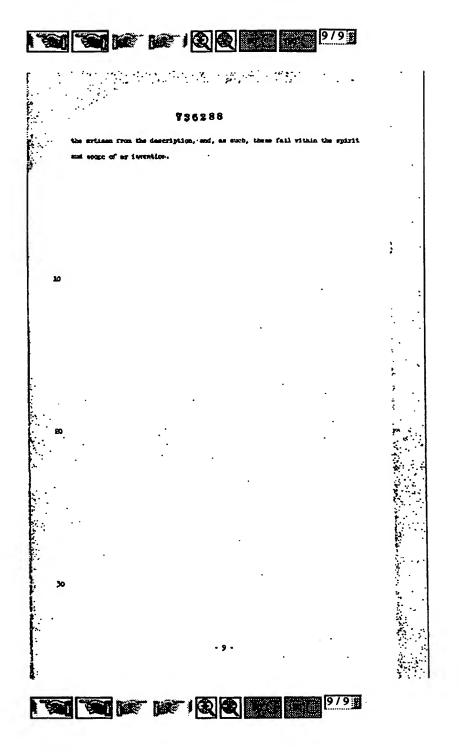
In emother test a spring device was built, as chose, employing 80 columns, each having a critical buckling load of 1250 younds. The internal deflication was limited between 0 and about 1.00 inches by expropriately positioning the steps. One empressional loading, the spring showest buckled at embetasticily 25,000 possess and from a longitudinal deflection of 0.04 inches (making) to about 0.15 inches the load remained substantially at 85,000 possess.

Or course, in dorigates a spring element as above it is advantagement to obtain the greatest possible value of longitudinal defluction for specified values of laboral defluction and artifical bushling load, while universing the atrees level to the columns at a case level. The preferred columns, therefore, are laminated, as shown in Figures 13 and 2, with militals flat unwhere making to seak column.

In the operation of the shows expecting tool for setting a liner in well exacted, the medo-up tool is lowered into the well as mentioned above, with the area 22 in the retreated position. When the tool is at the desired level, the well taking is revolved. The friction mether by engages with the wall of the making one prevents thinkle i) from revolving. With several revolutions of the taking, lower shoulder 35 is moved upwarely by differential entry 39 to bushle spring almost 37 which has a preferential without spring almost 37 which has a preferential without the lower and of computer 36, and its temperal surface is engaged with the tayonal surface on the leader of the orne 22 to argu the targe outwardly with a substantially constant force proportional to the critical bushling load of the spring almost. Exhaugmarily, the expanding tool is passed through the liner to expend it in the caping in the means described hereinbefore.

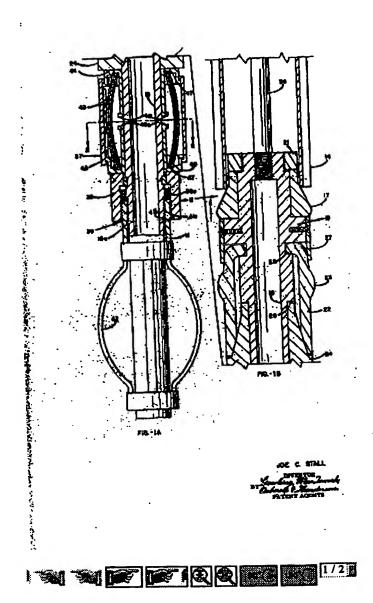
the foregring description of a preferred embedieset of my investion.

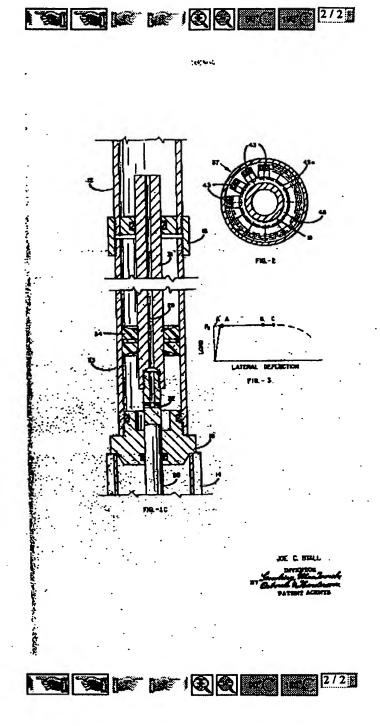
In all the understood that various mathifications and the description of approximation will become approximate.





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